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# (12) UK Patent Application (19) GB (11) 2 189 458 (13) A

(43) Application published 28 Oct 1987

(21) Application No 8610270

(22) Date of filing 26 Apr 1986

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(51) INTCL<sup>4</sup>  
B25J 17/02

(52) Domestic classification (Edition I)  
B8H 604 PD  
G1K 2C  
U1S 1881 B8H G1K

(56) Documents cited  
None

(58) Field of search  
B8H  
G1K  
Selected US specifications from IPC sub-class B25J

## (54) Compliant coupling mechanism

(57) A compliant mechanism 10 comprises a first coupling member 11 connected to a robot gripper 2, through a further compliant mechanism 100, and a second coupling member 12 connected directly to a robot arm 1. A spring 18 acts to align members 11, 12 co-axially along the Z-Z direction so that ball bearings 23 block respective openings 21 in member 12. If the gripper 2 is subjected to a substantial force, member 11 is displaced causing one or more ball bearings to be raised from their respective seatings. A monitoring system monitors the ingress or egress of air through the exposed openings and generates a control signal which, for example, is used to arrest further movement of the robot arm 1 and thus prevent damage to the gripper 2 and/or a component or tool carried thereby.

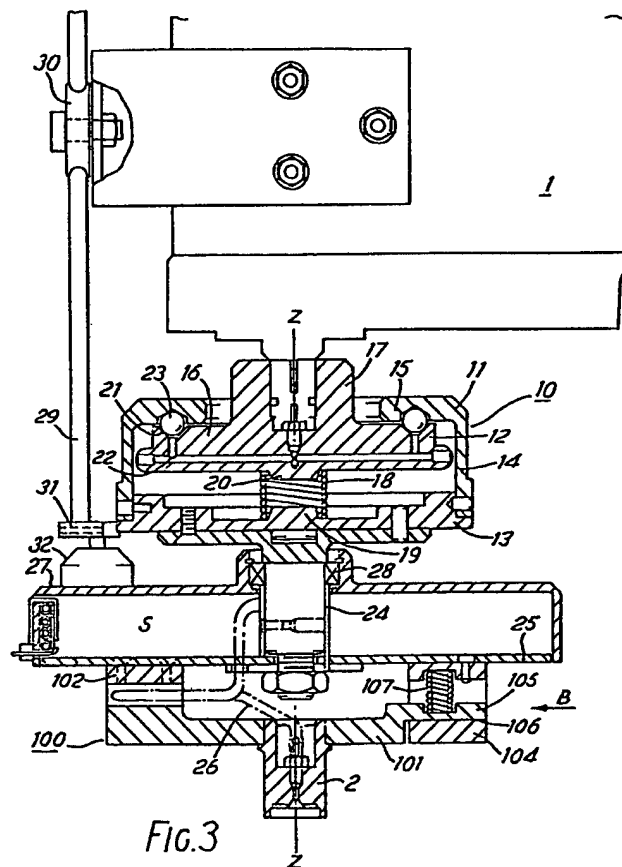
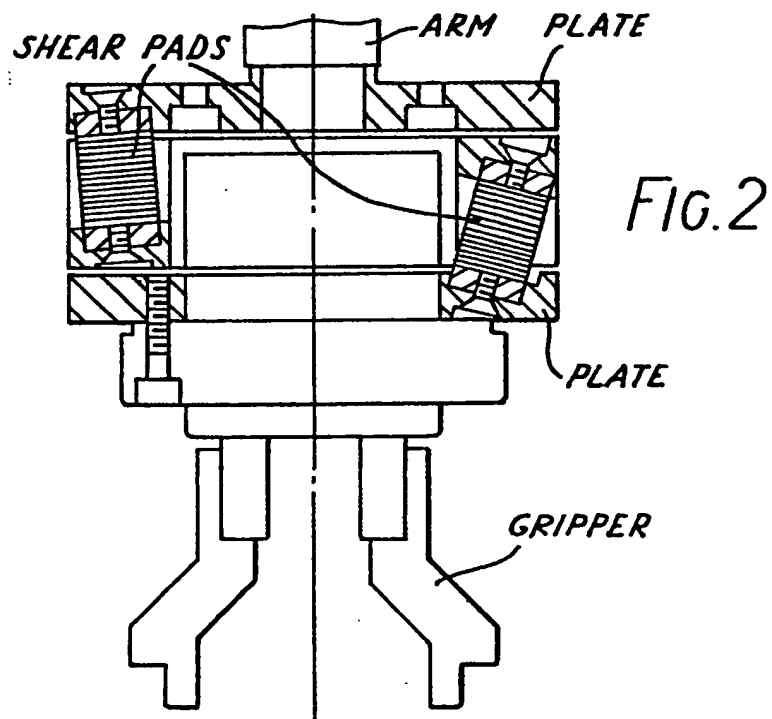
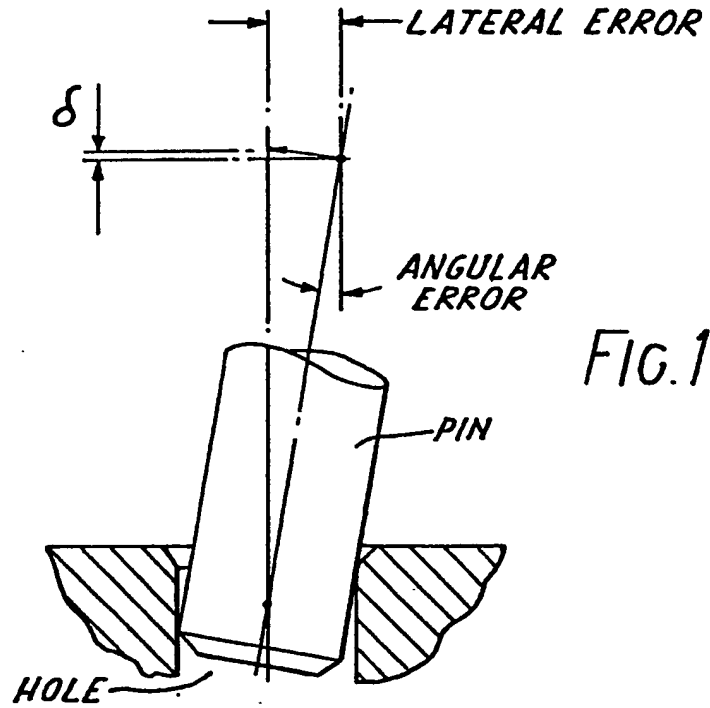


FIG. 3

The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

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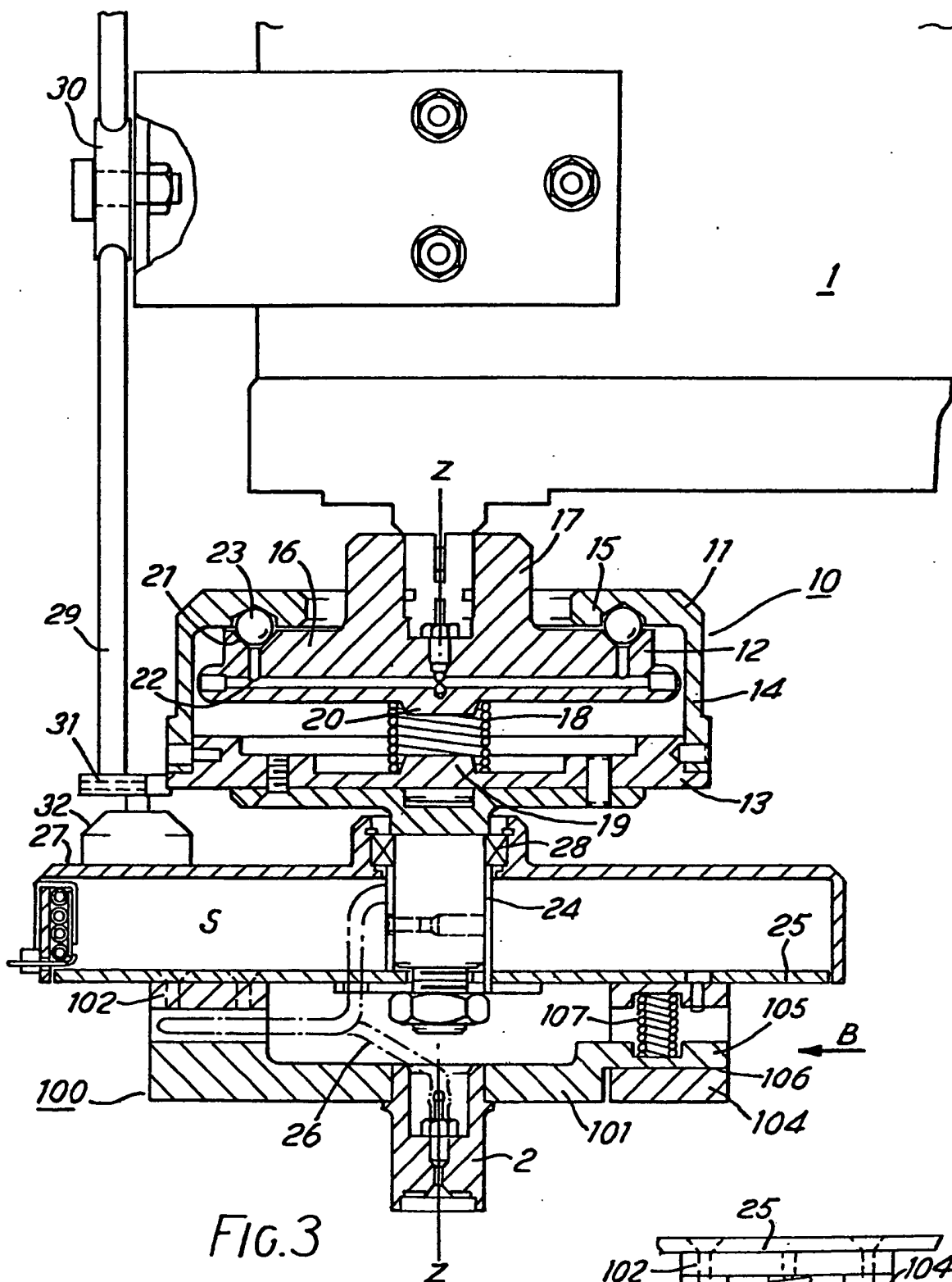


FIG. 3

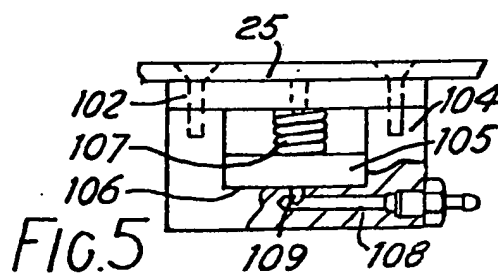


FIG. 5

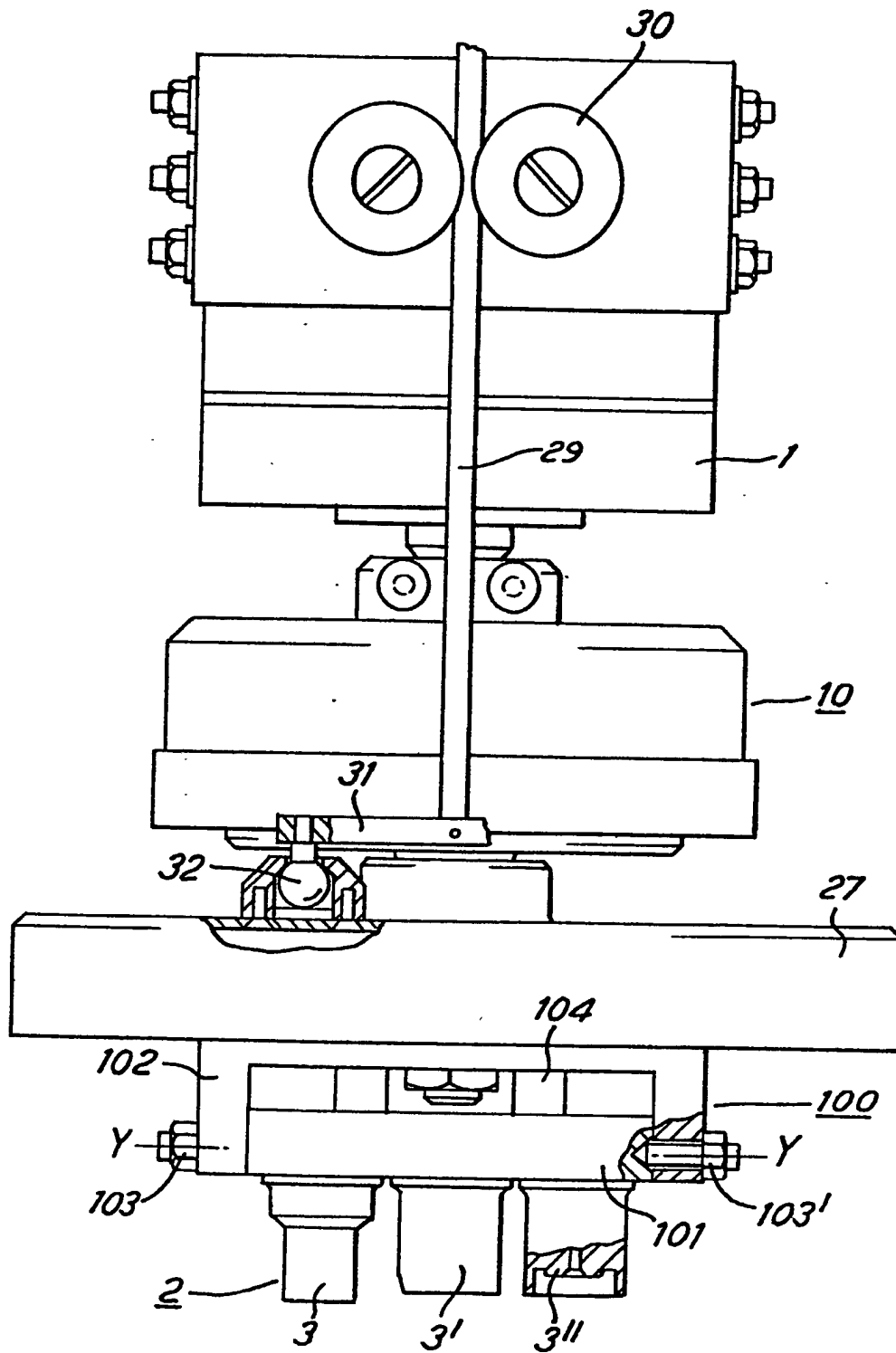


FIG. 4

## SPECIFICATION

### Compliant coupling mechanism

5 This invention relates to a compliant mechanism for coupling a robot gripper to a robot arm.

In some automated assembly and or processing operations the positional accuracy of a gripper in relation to a workpiece can be of critical importance.

10 Figure 1 of the accompanying drawings illustrates how both lateral and angular misalignment of a pin in relation to a hole could hinder insertion, and even cause jamming. A solution to the problem involves providing some form of compliant coupling  
15 mechanism which allows relative displacement of the gripper and arm in response to the prevailing forces. A known mechanism, shown in Figure 2, comprises two metal plates, one attached to the robot arm and the other to the gripper. The plates are  
20 joined together by a pair of elastomeric shear pads each consisting of a stack of metal and rubber washers arranged alternately. The shear pads are set at a slight angle so as to allow, in effect, rotational and or lateral displacement of the gripper relative to the arm. In some operational situations, however,  
25 especially in the case of accidental collision of parts, a coupling mechanism of this kind may not prevent damage to the gripper and or a component or a tool carried thereby. It is therefore an object of this  
30 invention to provide a compliant coupling mechanism which at least alleviates the above described problems.

Accordingly there is provided a compliant mechanism for coupling a robot gripper to a robot  
35 arm, the mechanism comprising a first member for coupling to the arm, a second member for coupling to the gripper and resilient means effective to bias the first and second members towards preset relative positions, wherein one of said first and  
40 second members has an air inlet (or outlet) opening connectable to an air pressure, or air flow monitoring system and the other of said first and second members is adapted to block said opening, to prevent ingress (or egress) of air, provided the first  
45 and second members assume preset relative positions, displacement of said first and second members from said preset relative positions allowing ingress (or egress) of air and causing the monitoring system to produce a response indicative  
50 of the displacement.

The monitoring system may generate a control signal effective to arrest further movement of the robot arm and so prevent damage to the gripper and or a component or tool carried thereby.

55 In one embodiment of the invention said one member has a plurality of recessed openings and said other member is provided with a corresponding plurality of blocking members, preferably ball bearings, which seat against, and so block, the  
60 respective openings when the first and second members assume said preset relative positions.

In another embodiment, said opening is formed in a surface of the first member and said second member is adapted to abut said surface directly, and  
65 block the opening, whenever said first and second

members are in said preset relative positions.

In order that the invention may be carried readily into effect particular embodiments thereof are now described, by way of example only, by reference to the accompanying drawings of which,

70 *Figure 1* illustrates lateral and angular misalignment of a pin in relation to a hole,

*Figure 2* shows a known form of compliant coupling mechanism,

75 *Figure 3* shows a longitudinal cross-sectional view through a compliant coupling mechanism in accordance with the present invention,

*Figure 4* shows a side elevation view of the compliant coupling mechanism shown in *Figure 3*,  
80 and *Figure 5* shows a different side elevation view, in direction of arrow B in *Figure 3*, of a part of the compliant coupling mechanism. Referring now to the *Figures 3* and *4* of drawings, a compliant mechanism shown generally at 10 couples a robot  
85 arm 1 to a robot gripper 2. In this particular example, the gripper comprises three independently, but simultaneously operable, suction heads 3, 3<sup>1</sup>, 3<sup>11</sup> each dedicated to a specific task. It will, however, be appreciated that any alternative form of gripper,  
90 known to those skilled in the art, could be used.

Mechanism 10 has two main parts, namely a first coupling member 11 connected to gripper 2 through a further (optional) compliant mechanism, shown generally at 100, and a second coupling member 12  
95 connected directly to the arm. Mechanism 100, also in accord with the present invention, will be described in greater detail hereinafter.

Member 11 comprises a generally circular base plate 13 mounting a cylindrical wall 14 formed with  
100 an annular flange 15, extending radially inwards, and member 12 comprises a disc 16 formed with a central boss 17 connected directly to the robot arm, as shown.

Disc 16 is confined in an enclosure bounded by the  
105 flange, wall and base plate, and a coil spring 18, which is located by respective upstanding formations 19, 20 on the disc and base plate, acts to press the disc resiliently against the flange. The disc has a number of recessed openings 21 formed at  
110 regular intervals around the boss, and a network of internal passageways 22 connects the openings to an air-pressure monitoring system (not shown) via a central coupling. The openings are shaped and dimensioned to seat respective ball bearings (eg 23)  
115 mounted at corresponding positions in a facing surface 24 of the flange.

In normal operation of the robot arm, spring 19 acts to align members 11, 12 coaxially along the Z-axis direction (shown as line ZZ in the drawing) so  
120 that the ball bearings are all seated firmly against, and so block, the respective openings. However, if the gripper is subjected to a substantial force, due to a collision, for example, acting along, and or transversely of, the Z-axis direction, member 11 is  
125 displaced with respect to member 12 causing one or more of the ball bearings to be raised from their respective seatings. In the case of a monitoring system operating at a reduced pressure, air enters the system via the exposed openings producing a  
130 detectable increase of pressure. In response, the

monitoring system generates a control signal which, in this example, is used to arrest further movement of the robot arm and so prevent damage to the gripper and or a component or tool carried thereby.

- 5 Alternatively, the control signal could be used to initiate a search routine whereby the robot arm is manoeuvred in accordance with a prearranged search pattern in such a way as to relieve the force acting on the gripper. It will be appreciated that, 10 alternatively, it would be possible to employ a monitoring system operating at an elevated pressure and in that case air can escape from the system via the exposed opening(s) to produce a detectable decrease of pressure. Alternatively it would be 15 possible to monitor flow, rather than pressure, of air in the system.

- As described hereinbefore, gripper 2 is coupled to compliant mechanism 10 through a further compliant mechanism 100. The suction heads, 3, 3<sup>1</sup>, 20 3<sup>11</sup> are arranged in side-by-side fashion on a common support plate 101 mounted pivotally in a shallow, generally U-shaped yoke 102. Plate 101 is supported on opposite sides by respective bearings 103, 103<sup>1</sup> which allow the plate to tilt, relative to the 25 yoke, about an axis YY orthogonal to ZZ. The yoke is fitted with a rectangular frame member 104, shown most clearly in Figure 5, and a flat finger 105, formed as an extension of plate 101, is pressed resiliently against an inner surface 106 of the frame member by 30 a coil spring 107. The frame member has an internal passageway 108 which connects an opening 109, formed in surface 106, to a further air pressure monitoring system (not shown in the drawings). In the illustrated position, finger 105 abuts surface 107 35 to block opening 109. However, should the gripper be subjected to a substantial transverse force, sufficient to overcome the resilience of spring 106, plate 101 can rock relative to the yoke causing the finger to move away from the opening. As in the case 40 of mechanism 10, the further air pressure monitoring system responds by producing a control signal effective to arrest further movement of the robot arm, though, as described hereinbefore, the control signal could alternatively be used to initiate a search 45 routine.

- Mechanism 10 is connected fixedly to mechanism 100 by a cylindrical shaft 24 attached centrally to a circular plate 25. Pneumatic lines (eg 26) servicing the suction heads are housed in a central supply duct 50 in the robot arm, independently of any gripper drive mechanism, and so sufficient lengths of line are stowed in an annular space S, enclosed by a protective cover 27, to accommodate a desired rotation of the gripper about the Z-axis-typically 55 through an angle up to 720°. The cover, to which the pneumatic lines are anchored, is mounted on shaft 24 through a ball race 28, and is prevented from rotating with the gripper by a rod 29 which is free to slide in runners 30 mounted on the robot arm, in 60 response to changes of axial position. Rod 19 is coupled to the cover through a lever arm 31 and a ball and socket joint 32 to accommodate pivotal displacement of the gripper and the associated compliant mechanisms. It will be appreciated that 65 mechanisms 10 and 100 operate independently of

one another, and although the described arrangement incorporates both mechanisms, alternative arrangements could may incorporate a single mechanism only.

70

## CLAIMS

1. A compliant mechanism for coupling a robot gripper to a robot arm, the mechanism comprising a 75 first member for coupling to the arm, a second member for coupling to the gripper and resilient means effective to bias the first and second members towards preset relative positions, wherein one of said first and second members has an air inlet 80 (or outlet) opening connectable to an air pressure, or air flow monitoring system and the other of said first and second members is adapted to block said opening, to prevent ingress (or egress) of air, provided the first and second members assume said 85 preset relative positions, displacement of said first and second members from said preset relative positions allowing ingress (or egress) of air and causing the monitoring system to produce a response indicative of the displacement.
- 90 2. A compliant mechanism according to Claim 1 wherein said one member has a plurality of recessed openings and said other member is provided with a corresponding plurality of blocking members which seat against, and so block, the respective openings 95 when the first and second members assume said preset relative positions.
3. A compliant mechanism according to Claim 2 wherein said blocking members are ball bearings.
4. A compliant mechanism according to Claim 1 100 wherein said opening is formed in a surface of the first member, and said second member is adapted to abut said surface directly, and so block the opening, whenever said first and second members are in said preset relative positions.
- 105 5. A compliant mechanism substantially as hereinbefore described by reference to the accompanying drawings.

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